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VAPOR BUBBLE LUMINESCENCE FROM DEEP SEA HYDROTHERMAL VENT MINERALS AND OTHER HOT SOLIDS

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Technical Report #5

March 30, 2001

ONR Grant N00014-00-1-0010

DEI SVB NVMINE VIGET

Vapor Bubble Luminescence from Deep Sea Hydrothermal Vent Minerals and Other Hot Solids

G.T. Reynolds

1. Introduction

Light from collapsing superheated steam bubbles has been reported by Chakravarty and Walton using an image intensifier.[1] At Walton's suggestion, the result was confirmed by Reynolds using a photomultiplier.[2] In a discussion concerning the visible light seen at deep sea hydrothermal vents, S.M. Gruner suggested that Reynolds look at the consequences of hot ($\sim$ 350°) vent materials encountering cold water. Such observations have been made and photomultiplier records indicate a burst of light exceeding the signal previously observed in the superheated steam bubble experiment. In addition, further observations with other hot solids show similar "light" signals.

2. Materials

a) Chips of sphalerite and chalcopyrite were obtained from Wards, Natural Science Establishment, Rochester, NY.

b) Core of Hawaiian rift basalt were obtained from USGS Laboratories, Denver, CO.

c) Samples of copper and iron were obtained from the Jadwin Physics Laboratory shop.

In the case a) chips were of various sizes, from a fraction of a millimeter to several millimeters in dimension. Sizes were mixed and the total volume of material was of the order of 0.5 to 1 ml. For the basalt b) two forms of samples were used: one in the form of a disk 25 mm diameter, 1.25 mm thick; the second sample was prepared in the form of chips as in the minerals a) above. In the case c) the copper was in the form of a block $1.5 \times 2.5 \times 0.5$ cm^3. The iron was $1.5 \times 1.5 \times 0.5$ cm^3 cm thick.

3. Method

The samples were heated to a temperature $\sim$300° C and dropped into a 300 ml beaker containing 150 ml water at room temperature ($\sim$18° C). This beaker was placed above the end window cathode of an RCA 8575 photomultiplier operated at 1700 volts. The signal was amplified by means of a

Keithley 610 A electrometer and recorded on a Soltec 1242 chart recorder. The chart paper was run at 60 mm min^{-1}. The response time of the system was too slow to provide any significant time resolution of the pulses to less than the width of the trace ($\sim$ 0.1 sec).

In addition to the photomultiplier experiments, the delivery system was placed in front of an intensified CCD Camera, Hamamatsu C2400-32, with a Century Optics 17 mm $f/0.95$ lens.

4. Results

In all cases a signal was observed from the photomultiplier (pm) when the hot material entered the water. Observations in room light confirmed that bubbles were seen (and heard) as the hot material settled in the water. The bubbles were of a variety of sizes. Representative signals are shown in Figures 1-6.

Figure 1 is a control run with beaker and water in place above the photomultiplier. The displacement up is the response when the voltage is turned on, the displacement down is the response to voltage off.

Figure 2, a,b, and c are responses to the introduction of sphalerite chips. The arrow points to the maximum displacement, clearly shown on the original but difficult to see on the copy of the record. 2a,b, and c indicate the lack of strict control of the delivery (done in the dark) and the various backgrounds due to various exposures to the hot beaker near the pm, to be discussed below.

Figure 3 is the response to the entry of hot chalcopyrite chips. The record shows that the chips did not all arrive together, and the response to the proximity of the hot beaker is evident.

Figure 4 is the response to the basalt. In a) a small quantity of chips were used. In b) and c) the disk was used. Inspection after the event showed that in case b the disk ended up in a position far off-center, out of view of the pm except perhaps at the instant of entry. In case c the disk ended up on the center of the beaker, over the pm and the record shows the result of several seconds of small bubble emission.

Figure 5 is the response to the block of copper. This was the largest response seen in any of the tests.

Figure 6 is the response to iron.

5. Summary

This work is obviously preliminary; the report is meant to urge that more carefully controlled experiments be conducted. Clearly some small hot hydrothermal vent minerals result in vapor bubble luminescence when they encounter cold water, and this effect can be added to the possible sources of vent light. Another direction is suggested by the fact that other hot metals exhibit the same effect, perhaps in relation to heat capacity, surface properties, etc.

As in the case of vapor bubble luminescence from superheated steam[(2] no convincing response was seen using the CCD. However, it is expected that the application of an image intensifier would be productive. Although the CCD failed to produce a convincing signal from hot solids entering cold water, the presence of the hot objects in the field of view resulted in a very distinct increase in the number of bright background noise on the monitor. This calls attention to the need to be aware that, although the response of cathodes appear to fall dramatically at long wavelengths as shown in Figures 7 and 8; and although thermal ("black body") radiation is low at the temperatures involved, the rapid increase of black body radiation at long wavelengths combined with the non-zero response of the cathodes at long wavelengths can distort results, and lead to misleadingly flat spectral distributions. (The same caution applies to supposedly "blocked" optical filters.)

References

1. A. Chakravarty and A.J. Walton, Light emission from collapsing superheated steam bubbles in water, J. Lumin. 92, 27-33 (2001).

2. G.T. Reynolds, Evidence for vapor bubble luminescence, Princeton University Technical Report #1, January 14, 2000.

Figures

Fig. 1 Control showing signal from turning pm voltage "on" and "off".

Fig. 2. Three records of the response when hot sphalerite chips enter cold tap water.

Fig. 3. Response due to hot chalcopyrite chips.

Fig. 4. a) Response to hot basalt chips;

b) response to basalt disk that ended up in the bottom of the beaker containing cold tap water well off center, out of view of the pm;

c) response to a delivery of the same disk as in b) that ended up over the center of the beaker, in full view of the pm.

Fig. 5. Strong response to a sample of hot copper plunged into cold tap water.

Fig. 6. Response to iron sample plunged into cold sea water.

Fig. 7. Quantum efficiency of pm cathode (#116).

Fig. 8. Quantum efficiency of CCD cathode, intensifier and chip.

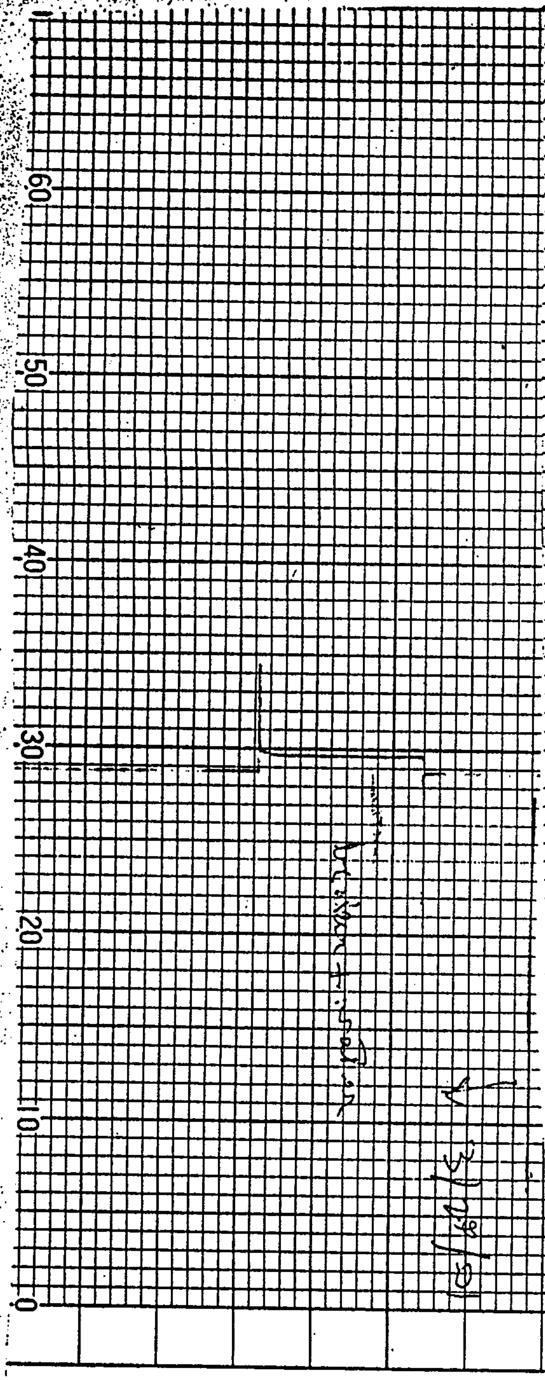


FIGURE 1

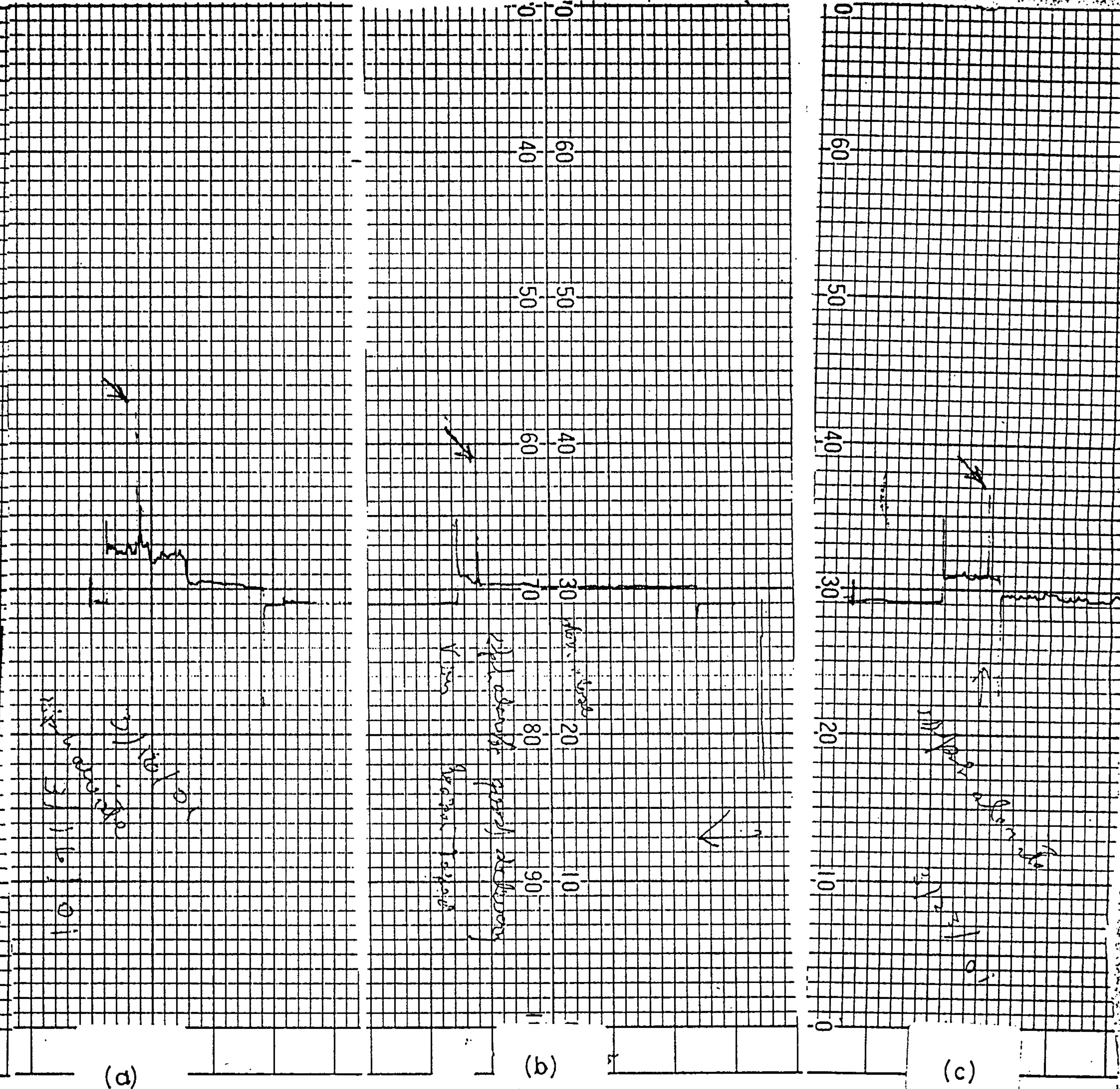


Figure 2

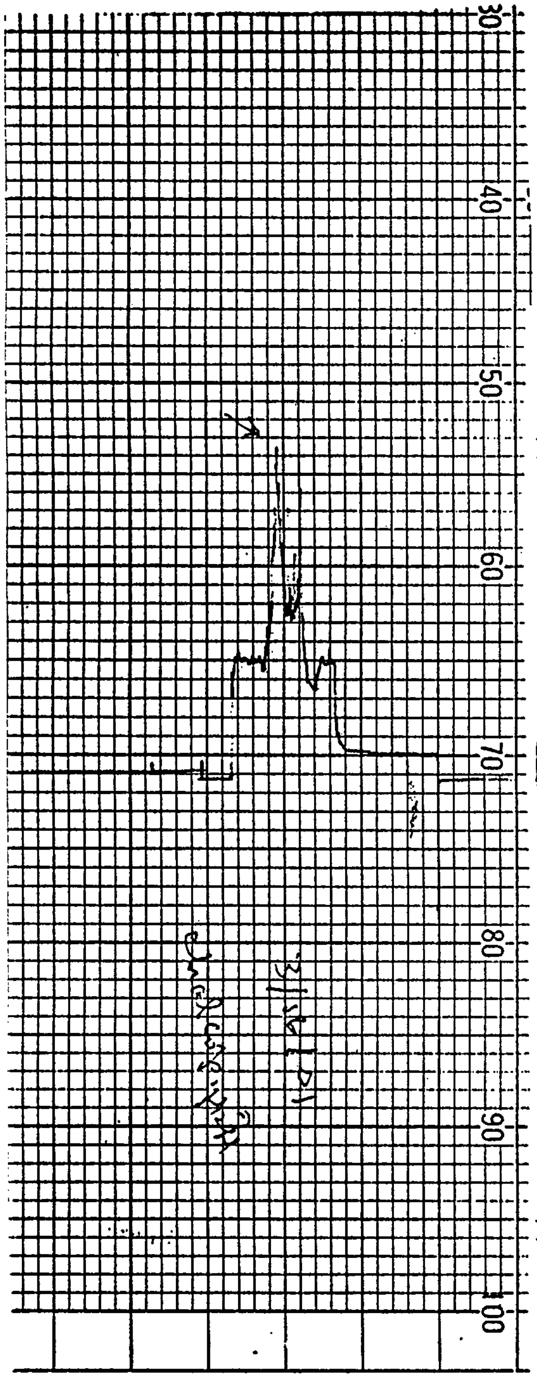
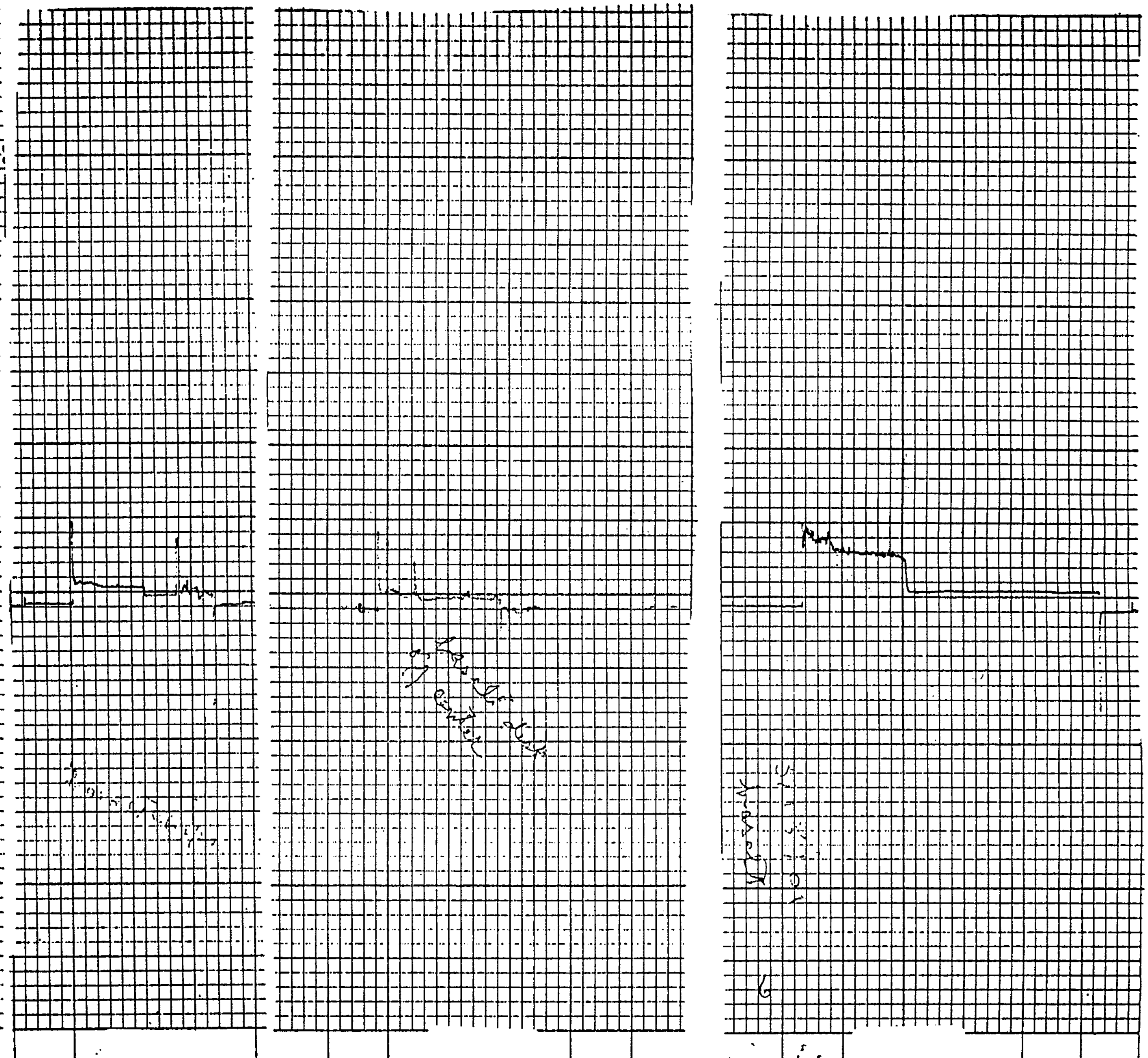


Figure 3



(a) (b) (c)

FIGURE 4

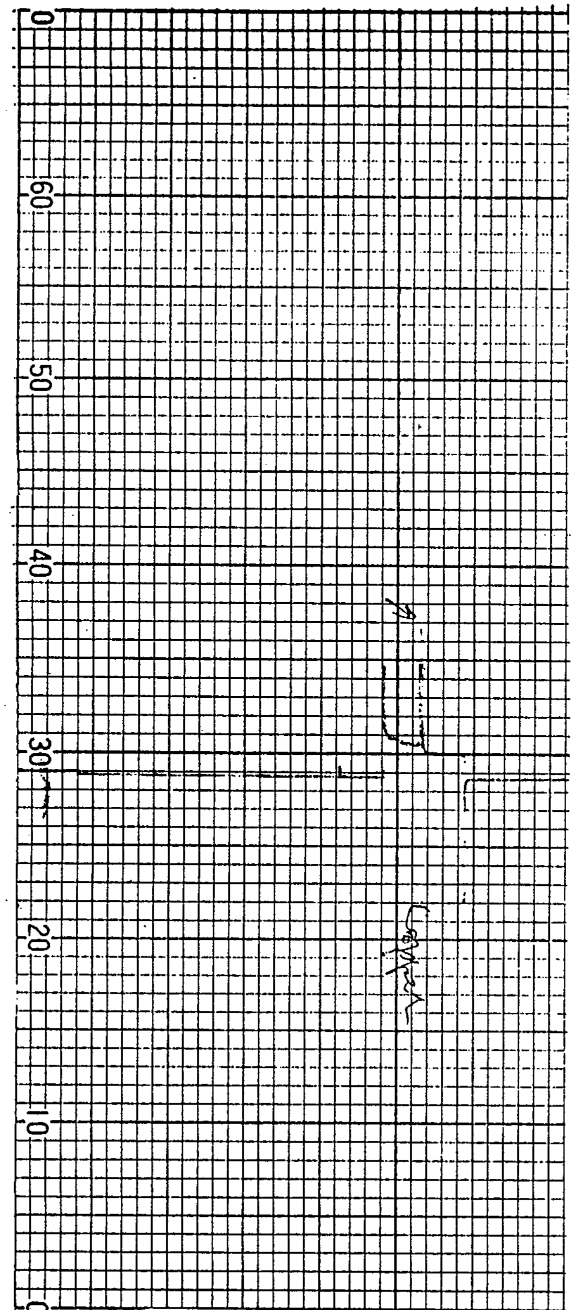


FIGURE 5

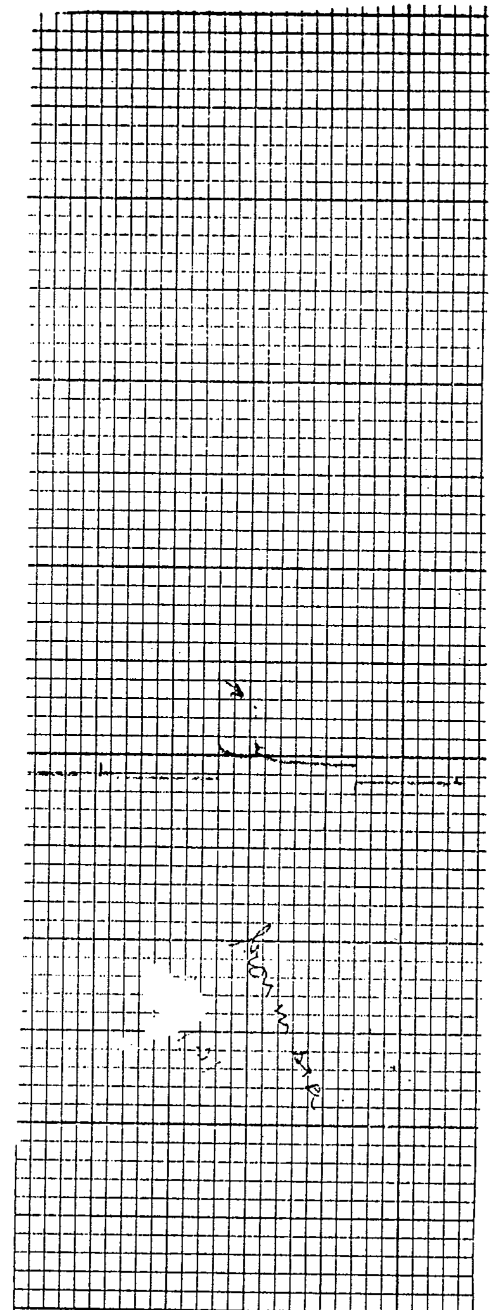
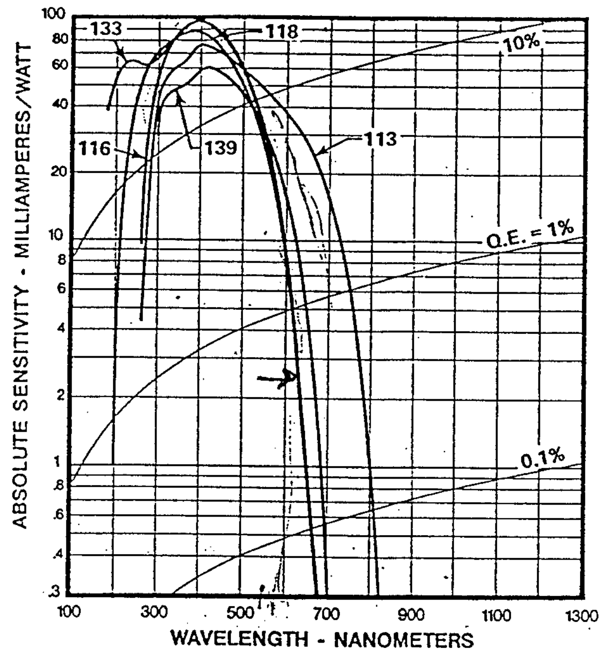
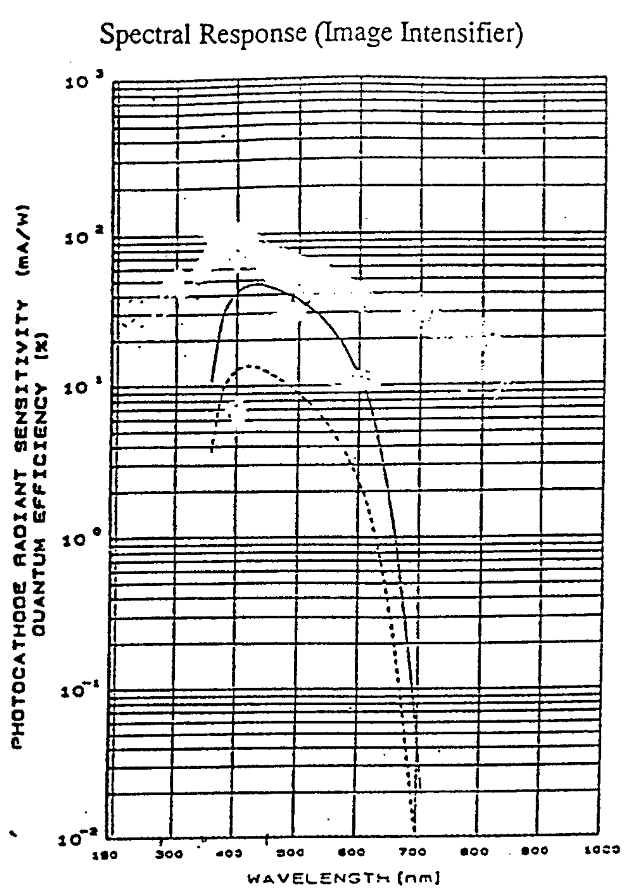


FIGURE 6



Typical Photocathode Spectral Response Characteristics

FIGURE 7



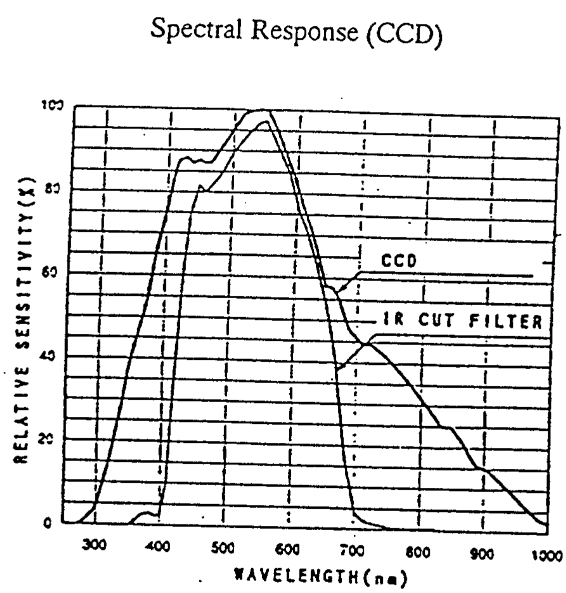


FIGURE 8

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: 30-03-2001

2. REPORT DATE: Technical

3. DATES COVERED *(From - To)*: 3/1/01 - 3/30/01

4. TITLE AND SUBTITLE
Vapor Bubble Luminescence from Deep Sea Hydrothermal Vent Minerals and Other Hot Solids

5a. CONTRACT NUMBER: PR -- 00PR00102-00

5b. GRANT NUMBER: N00014-00-1-0010

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)
G.T. Reynolds

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
The Trustees of Princeton University
Office of Research, Project Administration
Fourth Floor, New South Building
Princeton, NJ 08544-0636

8. PERFORMING ORGANIZATION REPORT NUMBER
PHYS-4

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Regional Office - Boston
495 Summer Street, Room 627
Boston, MA 02210-2109

10. SPONSOR/MONITOR'S ACRONYM(S)
ONR (73)

11. SPONSORING/MONITORING AGENCY REPORT NUMBER

12. DISTRIBUTION AVAILABILITY STATEMENT
APPROVED FOR PUBLIC RELEASE.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Vapor bubble luminescence, first notice when a jet of superheated steam enters cold water, has been observed when certain hot solids, 300°C, are dropped into room temperature water. The materials observed include several deep sea hydrothermal vent minerals, basalt, iron, and copper.

15. SUBJECT TERMS
Vapor bubble luminescence, hydrothermal vent minerals, thermal radiation

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	9	Geo. T. Reynolds
					19b. TELEPONE NUMBER *(Include area code)* (609) 258-4384

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI-Std Z39-18